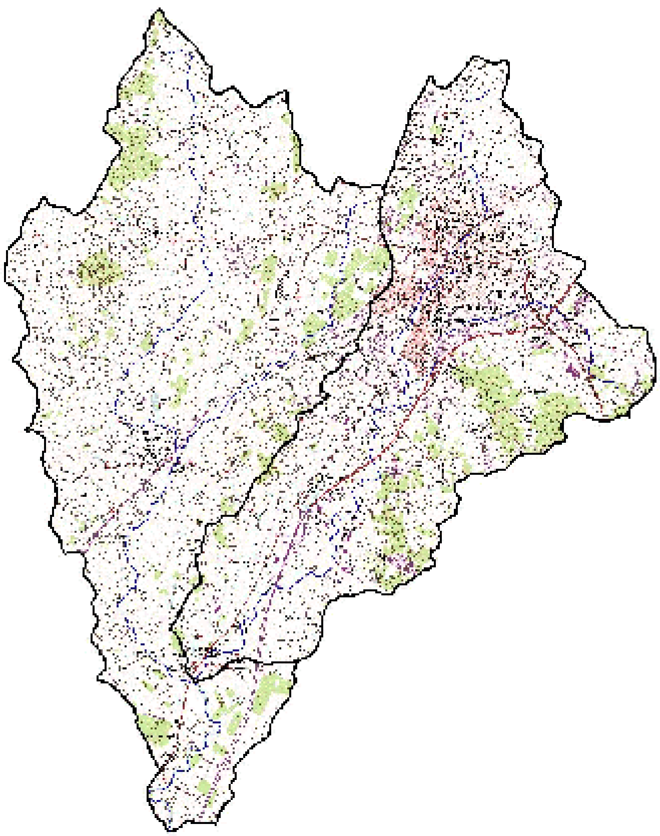
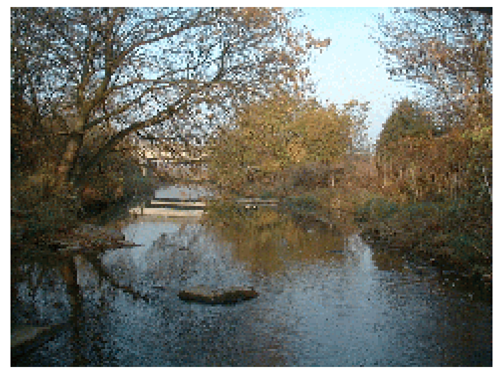
Total Maximum Daily Load (TMDL) Development for Cooks Creek

Fecal Coliform Bacteria Impairment





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U.S. Environmental Protection Agency, Region III
Virginia Department of Environmental Quality
Virginia Department of Conservation and Recreation

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SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991).

1.1.2 Impairment Listing

Cooks Creek was listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's water quality standards for fecal coliform bacteria and violations of the General Standard (Benthics) (VADEQ 1998). The Cooks Creek segment begins at the headwaters and continues to its confluence with the North River (13.32 miles in length). This report will address the fecal coliform bacteria impairment on Cooks Creek. Benthic TMDLs for Cooks Creek were also developed and are presented in a companion report.

A TMDL for fecal coliform bacteria on Blacks Run (main tributary to Cooks Creek) is being developed concurrently by the United States Geological Survey (USGS) under a separate contract.

1.1.3 Watershed Location

Cooks Creek is located in Rockingham County, Virginia in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005) (Figure 1.1). The waterbody identification codes (WBID, Virginia Hydrologic Unit) for the Cooks Creek watershed is VAV-B25R (VADEQ 1998). Blacks Run drains much of the City of Harrisonburg and is the main tributary to Cooks Creek.

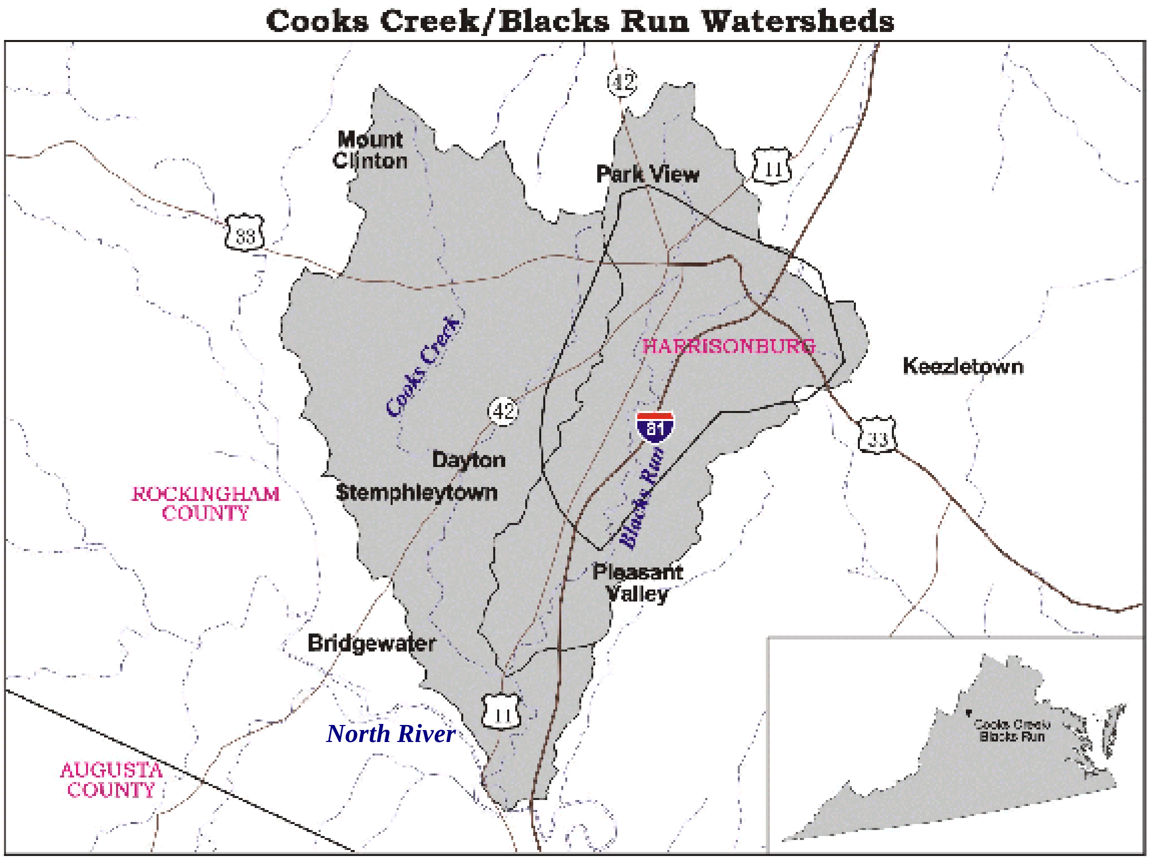

Figure 1.1 Location of the Cooks Creek and Blacks Run watersheds

1.2 Designated Uses and Applicable Water Quality Standards

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "Water quality standards" *means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§ 62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC § 1251 et seq.).*

1.2.1 Designation of Uses (9 VAC 25-260-10)

A. All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).

Cooks Creek does not support the recreational (swimming) and aquatic life designated uses due to violations of the general (benthic) criteria and fecal coliform bacteria criteria (see below).

1.2.2 Water Quality Standards

General Criteria (9 VAC 25-260-20)

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

Fecal Coliform Bacteria (9 VAC 25-260-170)

A. General Requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.

1.2.3 Water Quality Standards Review

Two regulatory actions related to the fecal coliform water quality standard are currently under way in Virginia. The first rulemaking pertains to the indicator species used to measure bacteria pollution. The second rulemaking is an evaluation of the designated uses as part of the state’s triennial review of its water quality standards.

<u>Indicator Species</u>

EPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. In Virginia, the adoption of the *E. coli* and enterococci standard is scheduled for 2002.

<u>Designated Uses</u>

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard as described in 9 VAC 25-260-170 is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream." It is obvious that many streams within the state are not used for primary contact recreation.

Additionally, the VADEQ and VADCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or “typing” of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl contribute to the elevated fecal bacteria counts in these streams.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, Virginia is considering re-designation of the swimming use for secondary contact in cases of: 1) natural contamination by wildlife, 2) small stream size and 3) lack of accessibility to children. The widespread socio-economic impacts resulting from the cost of improving a stream to a “swimmable” status are also being considered.

The re-designation of the current swimming use in a stream to a secondary use will require the completion of a Use Attainability Analysis (UAA). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

1.3 Fecal Coliform Bacteria Monitoring and Assessment

Fecal coliform bacteria data and closures issued by the Virginia Department of Health (VDH) are used to determine whether a waterbody meets the Recreational (swimming) designated use. Ambient water quality monitoring is performed by VADEQ on a monthly, bimonthly, or quarterly basis. This sampling frequency does not provide the required two or more samples within a 30 day period to calculate the geometric mean, therefore, fecal coliform bacteria data are assessed using the 1000cfu (colony forming units)/100ml (instantaneous) criteria. For the 1998 303(d) report, the assessment period included the previous five years of water quality data, from July 1, 1992 through June 30, 1997.

Waters are listed as impaired for the Recreational (swimming) designated use if greater than 10% of the fecal coliform bacteria data exceed the 1000 cfu/100 ml criteria. For the 1998 305(b) and 303(d) reports, VADEQ used the binomial assessment method to determine the percent violation rate for conventional pollutants, including fecal coliform bacteria, rather than an arithmetic division of number of exceedances by the number of samples. The binomial assessment method is a statistically-based method that balances the likelihood of over-regulation versus under-regulation. The percent violation rate calculated using both methods is equivalent at higher sample sizes (>35 samples). A sufficient number of exceedances of the fecal coliform bacteria criteria (>10%, using either method) were recorded for Cooks Creek during the assessment period to list the stream as impaired.

SECTION 2

STREAM AND WATERSHED CHARACTERIZATION

2.1 Watershed Characterization

2.1.1 General Information

Cooks Creek is located in Rockingham County, Virginia in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005), which is part of the Chesapeake Bay watershed. The waterbody identification code (WBID, Virginia Hydrologic Unit) for the Cooks Creek watershed is VAV-B25R (VADEQ 1998). Blacks Run drains much of the City of Harrisonburg and is the main tributary to Cooks Creek. Blacks Run is 10.74 miles in length with a watershed of approximately 12,255 acres. Cooks Creek is located just west of Harrisonburg. This tributary to the North River is 13.32 miles in length and drains approximately 28,174 acres (including the Blacks Run subwatershed).

2.1.2 Geology

Cooks Creek is located in the Shenandoah Valley of Virginia, which is part of the Valley and Ridge physiographic province. The Valley and Ridge physiographic province is a belt of folded and faulted clastic and carbonate sedimentary rocks situated west of the Blue Ridge crystalline rocks and east of the Appalachian Plateaus. The Shenandoah Valley makes up part of the Great Valley subprovince, which extends from New York southwest to Alabama. This area is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks. Limestone and dolomite (which are carbonate rocks) occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. The gently rolling lowland of the valley floor lies at an elevation of approximately 1000 feet above sea level. Sinkholes, caves, and caverns are common in the valley due to its karst (carbonate rock) geology.

2.1.3 Soils

Soils data were obtained from the Rockingham County Soil Survey (SCS 1981) and the State Soil Geographic (STATSGO) database for Virginia, as developed by the Natural Resources Conservation Service (NRCS 1994). The Rockingham County Soil Survey identifies three primary soil associations in the Cooks Creek watershed, as shown in Figure 2.1.

The Frederick-Lodi-Rock Outcrop and Chilhowie-Edom soil associations include valley soils that were formed in residual material weathered from limestone, dolomite, and calcareous shale. Frederick-Lodi-

Rock Outcrop soils are located in the eastern and western sections of the Cooks Creek watershed (STATSGO map unit - VA003). Chilhowie-Edom soils are located in the central portion of the Cooks Creek watershed (STATSGO map unit - VA002). These soils are generally deep to moderately deep, gently sloping to steep, well drained soils that have a clayey subsoil and areas of rock outcrop, and are located on uplands underlain by limestome, dolomite, and interbedded shale. Infiltration is slow to moderate and runoff potential is moderate. Slopes typically range from 2 to 60 percent. The soils are fertile and cleared areas are commonly used for cropland and pasture. Corn and hay are the principal crops grown in these areas. Forested areas consist of northern red oak, yellow poplar, hickory, maple, black walnut, locust, eastern red cedar, and Virginia pine.

The third soil association, Monongahela-Unison-Cotaco, exists in the southern and southwestern portions of the Cooks Creek watershed (STATSGO map unit - VA004). This soil map unit follows the floodplain of the North River and other streams in the county, including downstream areas of Cooks Creek. These soils are found on river terraces that formed in alluvial or colluvial material. Soils are generally level to moderately steep, well drained to moderately well drained, and have a loamy or clayey subsoil. Infiltration is slow in the fragipan and surface runoff is moderate. Slopes range from 0 to 25 percent. Most areas have been cleared of the original hardwood forest and used for pasture, cultivated crops, and industrial and residential sites. Corn and hay are the principal crops grown in these soils.

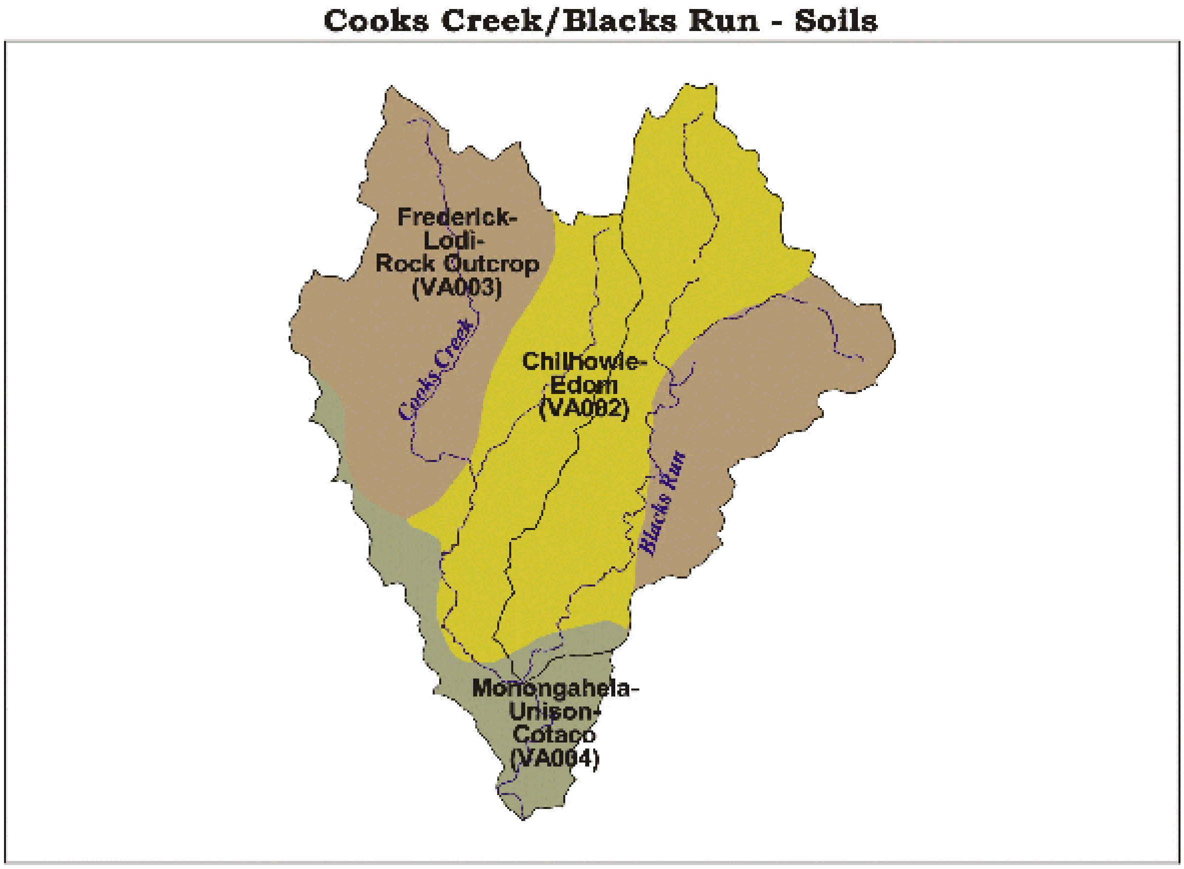

Figure 2.1 Soil associations and STATSGO map units in Cooks Creek and Blacks Run

2.1.4 Climate

The area's climate is typical of other regions in the Shenandoah Valley. The Blue Ridge Mountains to the east and the Alleghany Mountains to the west provide protection from the climate extremes experienced in other parts of Virginia. Weather data for these watersheds can be characterized using the Dale Enterprise meteorological station, which is located in the northwestern portion of the Cooks Creek watershed (period of record: 1961-1990). The growing season lasts from May 1 through October 11 in a typical year (SERCC 2000). Average annual precipitation is 33.6 inches with August having the highest average precipitation (3.58 inches). Average annual snowfall is 26.5 inches, most of which occurs in January and February. The average daily temperature for the year is 53.3ºF. The average annual maximum and minimum daily temperature is 64.9ºF and 41.7ºF, respectively. The highest daily average temperatures are recorded in July (85.8ºF) and the lowest temperatures are recorded in January (21.1ºF).

2.1.5 Land Use

A GIS land use coverage was developed by the Virginia Department of Conservation and Recreation (VADCR) for the Cooks Creek watershed in the early 1990s using satellite imagery (Figure 2.2). Land use areas in these watersheds were ground-truthed by VADCR and Tetra Tech personnel in October 2000 and corrections to GIS coverages were made using this information and housing coverages provided by the planning offices of Rockingham County and the City of Harrisonburg. There are a total of 25 unique land use types in the GIS coverages, including various urban, agricultural, and forest categories (Table 2.1). Individual land use types were consolidated into ten broader categories that had similar attributes for modeling purposes.

Land use in the Blacks Run watershed is predominantly urban/suburban in the middle and upper portions of the watershed and agricultural in the lower portion. Overall, 66% of the Blacks Run watershed is urban/suburban, 16% is pasture/hayland, 9% is cropland, and 8% of the area is forest. Much of the City of Harrisonburg is located within the Blacks Run watershed, which accounts for the high percentage of urban area. Primary and secondary roads, including Interstate 81 and U.S. Highways 33 and 11, bisect the watershed and have helped support urban development in the area. The City of Harrisonburg has a population of approximately 40,468 people according to the 2000 Census. James Madison University is located within the City of Harrsionburg and is a major state university. The university and residential areas include large areas of green space, therefore, much of the classified urban area in the watershed consists of pervious lands. Agricultural land uses consist of cropland (primarily corn production), hayland, pasture, and livestock operations. Livestock in the watershed include dairy and beef cattle, hogs, sheep, chickens, and turkeys.

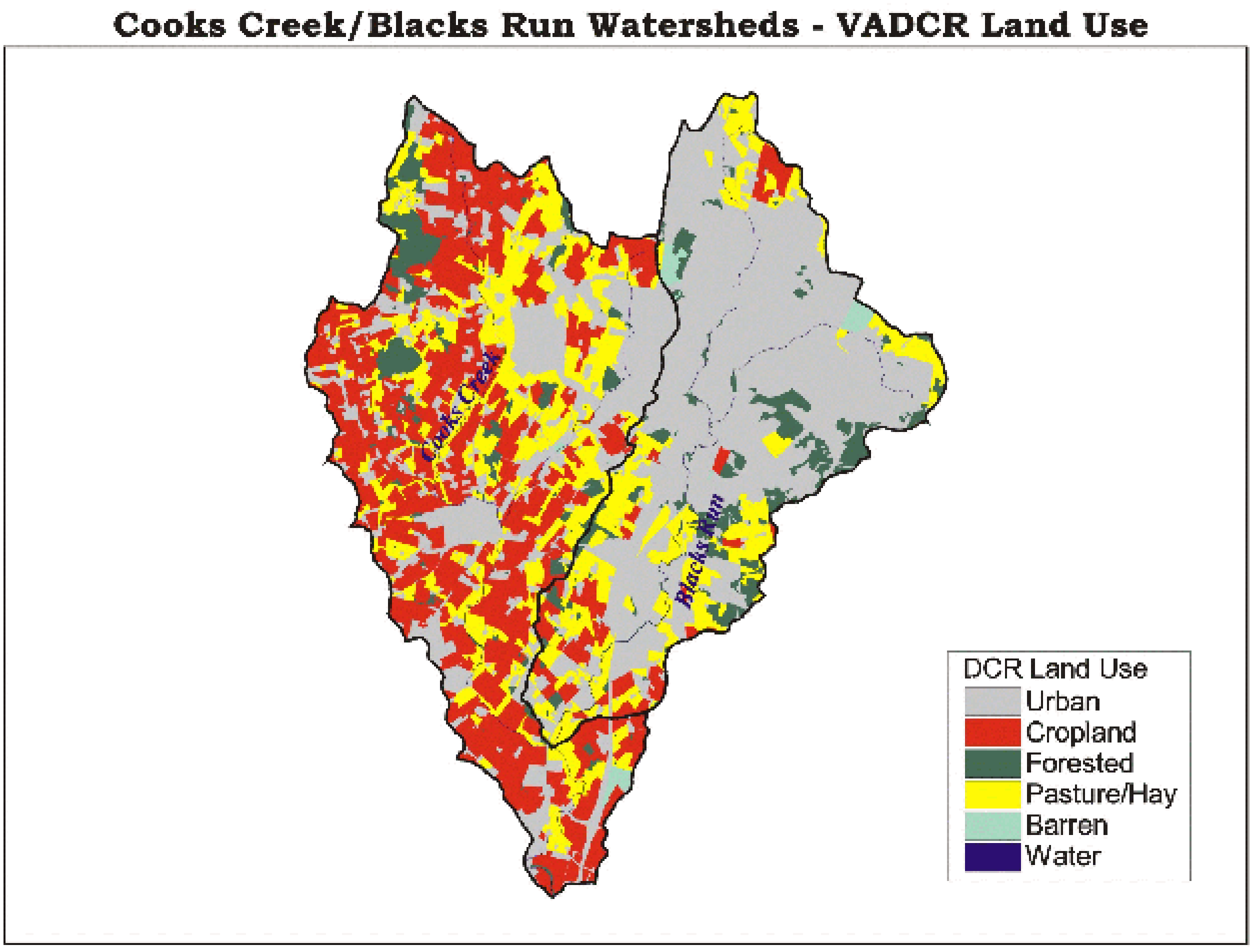

Figure 2.2 Land use in the Cooks Creek and Blacks Run watersheds (VADCR)

The Cooks Creek watershed is predominantly agricultural except for the Blacks Run portion. The entire Cooks Creek watershed, including Blacks Run, is 43% urban/suburban, 28% cropland, 21% pasture/hayland, and 8% forest. Excluding the Blacks Run subwatershed, the watershed is 26% urban, 41% cropland, 26% pasture/hayland, and 7% of the area is forest. Urban areas in the watershed include Mount Crawford, Park View, Dale Enterprise, the Town of Dayton, and the City of Harrisonburg (Blacks Run). The Town of Dayton is the second largest urban area in the watershed with a population of 1,344 people (Census 2000). Overall, the percentage of urban area is significantly lower than in the Blacks Run watershed. Also, urban development is less concentrated and primarily consists of low intensity residential areas. Agricultural land uses, cultivated crops, and livestock grown in the watershed are the same as those listed above for Blacks Run. The livestock population in the Cooks Creek watershed is considerably higher than in the Blacks Run watershed.

Table 2.1 VADCR land use categories and consolidated land uses

VADCR land use Categories	Consolidated land use
Crop Land	Row Crops
Improved Pasture Unimproved Pasture Overgrazed Pasture Rotational Hay	Pasture/Hay
Barren Cattle Operations	Transitional
Open Urban Land	Urban / Recreational Grasses
Commercial and Services Industrial Transportation	High Intensity Commercial / Industrial / Transportation
High Density Residential Mixed Urban or Built-Up Mobile Home Park	High Intensity Residential
Medium Density Residential	Medium Intensity Residential
Low Density Residential Farmstead Large Dairy Waste Operations Poultry Operations	Low Intensity Residential
Forested Grazed Woodland Nurseries and Christmas Tree Farms Orchards Wooded Residential	Forest
Water	Water

2.2 Stream Characterization

Blacks Run flows through downtown Harrisonburg and continues through a predominantly agricultural area in the lower reach. Views of Blacks Run and its watershed are shown in Figure 2.3. Several mainstem and tributary sections were placed in underground culverts years ago to allow for construction of city buildings and other structures. Other sections have been channelized and urban encroachment into riparian areas has occurred. Streams show evidence of de-stabilization including bank erosion, down-cutting (erosive deepening of the stream channel), and excessive sedimentation. This de-stabilization is likely caused by hydromodification of the stream channel due to increased runoff from impervious areas and stormwater outfalls during storm events. Stream banks have been armored with rip-rap or retaining walls in some sections to prevent bank erosion and slumping. Downstream areas of Blacks Run have also been negatively impacted by erosion from agricultural lands and riparian disturbances. Riparian vegetation is minimal throughout the watershed.

Cooks Creek has been primarily affected by agricultural practices, including the intensive use of riparian areas for cropland and pasture. Views of Cooks Creek and its watershed are shown in Figure 2.4. Erosion from cropland and overgrazed pasture land is primarily responsible for observed sedimentation problems. Livestock traffic has also resulted in bank erosion and other physical impacts to stream channels. Most riparian areas are in crop production or are utilized as pasture for grazing livestock. Urban development in the watershed, excluding Blacks Run, is less intense and is not generally concentrated within a close proximity to streams. As in Blacks Run, riparian vegetation is minimal throughout the watershed.

Figure 2.3 Views of Blacks Run (photos taken on 10/27/00)

Figure 2.4 Views of Cooks Creek (photos taken on 10/27/00)

SECTION 3

TMDL ENDPOINT AND WATER QUALITY SUMMARY

3.1 TMDL Endpoint Determination - Fecal Coliform Bacteria

Cooks Creek was listed as impaired for fecal coliform bacteria on Virginia's 1998 303(d) list based on monitoring conducted from July 1, 1992 through June 30, 1997. Elevated levels of fecal coliform bacteria were recorded at the VADEQ water quality monitoring station on Cooks Creek during this time period. As a result, Cooks Creek does not support the Recreation (swimming) beneficial use.

As discussed previously, TMDL development requires the identification of a numeric endpoint that will allow for the attainment of designated uses and water quality criteria. For the Cooks Creek fecal coliform bacteria TMDL, the applicable endpoint can be determined directly from the Virginia water quality regulations. Water Quality Standards specify a maximum fecal coliform bacteria concentration of 1000 cfu/100ml, at any time, and a geometric mean criteria of 200 cfu/100 ml for two or more samples over a 30-day period (9 VAC 25-260-170). The geometric mean criteria was used as the TMDL endpoint because continuous simulation modeling results are presented at daily intervals, which provides more than the minimum number of samples required for calculation of the geometric mean. Therefore, the in-stream fecal coliform target for this TMDL was a geometric mean not exceeding 200 cfu/100ml.

3.2 Monitoring Stations

Monthly fecal coliform bacteria data are collected by VADEQ at Ambient Water Quality Monitoring (AWQM) stations on Cooks Creek and Blacks Run. Benthic community data are collected at separate biomonitoring stations each spring and fall. The USGS and VADEQ also maintain a flow gaging station on Blacks Run that was in operation from February 1999 through January 2001. Station locations are listed in Table 3.1 and shown in Figure 3.1. The AWQM station on Cooks Creek is located upstream of its confluence with Blacks Run.

Table 3.1 Monitoring stations on Blacks Run and Cooks Creek

Station Type	Station Number	Stream and Location
AWQM	1BBLK000.38	Blacks Run - near the mouth, approximately 600 feet downstream of the Rt. 704 bridge
	1BCKS003.10	Cooks Creek - just upstream of the confluence with Blacks Run, at the Rt. 11 bridge
Biomonitoring	1BBLK005.62	Blacks Run - upstream, near a gravel parking lot off of Beery Road in Harrisonburg
	1BCKS003.04	Cooks Creek - just downstream of the AWQM station, between Rt. 11 and the confluence with Blacks Run
USGS Streamflow Gage	01621470	Blacks Run - at the Rt. 704 bridge

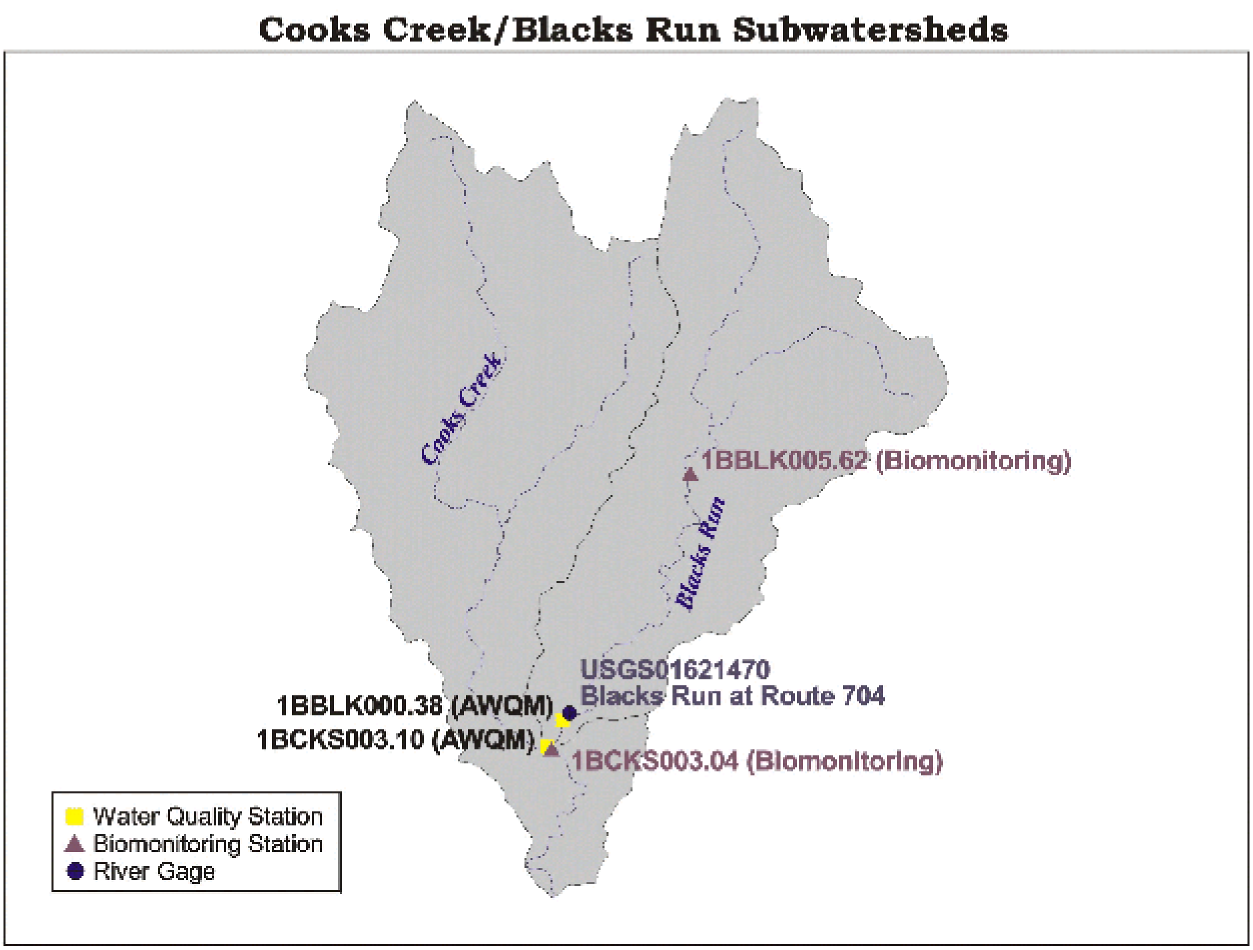

Figure 3.1 Monitoring stations on Cooks Creek and Blacks Run

3.3 Water Quality Summary

3.3.1 Ambient Water Quality Monitoring (AWQM) Summary

Cooks Creek is classified as a Mountainous Zone Waterbody (Class IV) in Virginia Water Quality Standards (9 VAC 25-260-50). Numeric criteria for dissolved oxygen, pH, and maximum temperature for Class IV waters are shown in Table 3.2.

Table 3.2 Virginia numeric criteria for Class IV waters

Dissolved Oxygen (mg/L)			
Minimum	Daily Average	pH (standard units)	Maximum Temperature (ºC)
4.0	5.0	6.0 - 9.0	31

Water quality monitoring data were summarized to help determine general stream characteristics (Table 3.3). These data were collected by VADEQ from December 1991 through October 2000. VADEQ began analyzing for low-level concentrations of total phosphorus in Blacks Run and Cooks Creek in April 1994. Therefore, total phosphorus data presented in Table 3.3 were collected from April 1994 through October 2000.

Table 3.3 Water quality summary for Blacks Run and Cooks Creek

Parameter Name	Temp (°C)	DO (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	NH3+NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	Fecal Coliform (cfu/100ml)
1BBLK000.38 (Blacks Run)									
Count	99	98	99	80	99	98	98	81	96
Mean	14.58	10.35	8.11	28.94	36.56	0.14	1.61	0.097	5292
Median	15.10	10.30	8.10	14.35	17.00	0.04	1.45	0.060	2300
Max	29.90	16.10	9.30	520.00	784.00	4.00	6.97	0.900	16000
Min	0.10	4.40	7.00	3.00	3.00	0.04	0.28	0.020	45
1BCKS003.10 (Cooks Creek)									
Count	99	98	99	80	99	98	98	81	97
Mean	14.71	9.91	8.11	60.10	68.90	0.20	4.85	0.258	7361
Median	14.50	10.05	8.10	29.70	40.00	0.12	4.12	0.170	6400
Max	30.00	15.30	9.50	390.00	506.00	1.69	9.45	1.410	16000
Min	0.20	3.30	7.00	6.45	4.00	0.04	0.39	0.040	100

By comparison, Cooks Creek had poorer water quality than Blacks Run for each parameter shown. Nutrients, total suspended solids, fecal coliform bacteria, and other water quality parameters were elevated above typical background concentrations in both streams indicating degraded water quality conditions.

3.3.2 Fecal Coliform Bacteria Data

As discussed in Section 1, fecal coliform bacteria data are assessed using the 1000 cfu/100 ml (instantaneous) criteria. VADEQ monitoring data collected from December 1991 through October 2000 were analyzed to determine the percent violation of the 1000 cfu/100ml criteria. Fecal coliform bacteria counts for Cooks Creek and Blacks Run are shown in Figures 3.2 and 3.3, respectively. During this time period, Cooks Creek had a percent violation rate of 90% and Blacks Run had a percent violation rate of 75%.

Of particular note is the number of samples that had a fecal count of 16,000 cfu/100 ml. The upper limit of laboratory analysis was either 8,000 cfu/100 ml or 16,000 cfu /100 ml, depending on collection date. Therefore, many of these samples likely represent concentrations much higher than these limits. The percent violation analysis and the number of extremely high concentrations provide insight into the magnitude of the fecal contamination problems in these streams. Violations occurred in all flow regimes.

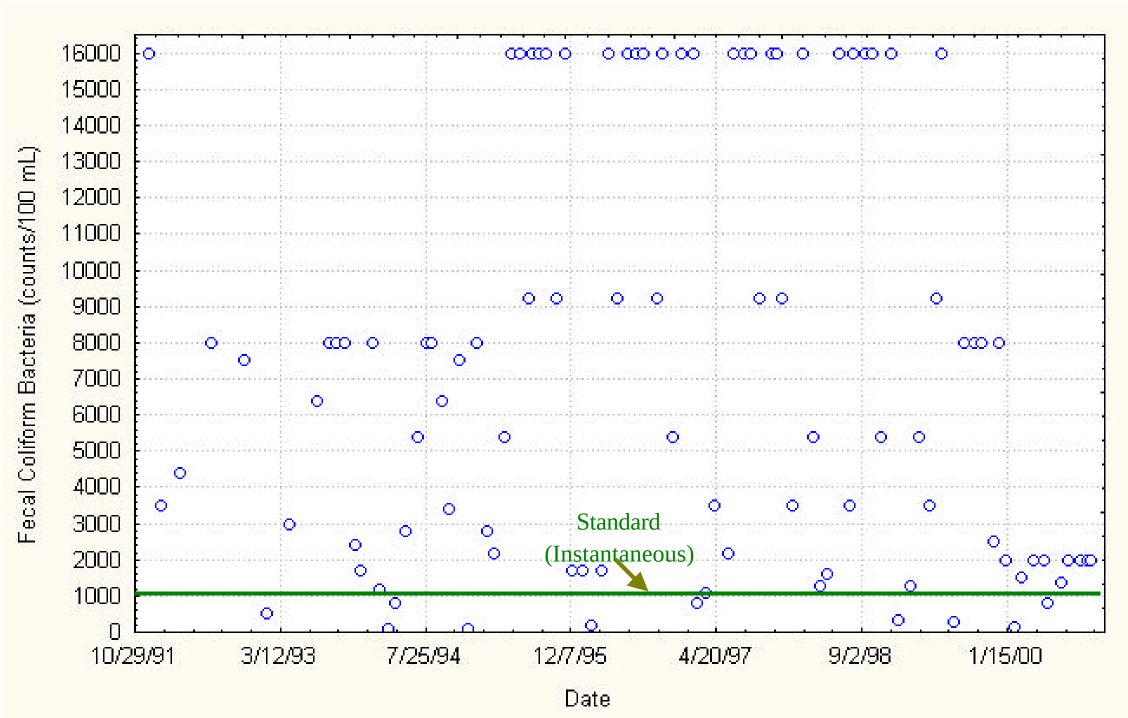

Figure 3.2 Cooks Creek - fecal coliform bacteria data (12/91 - 10/00)

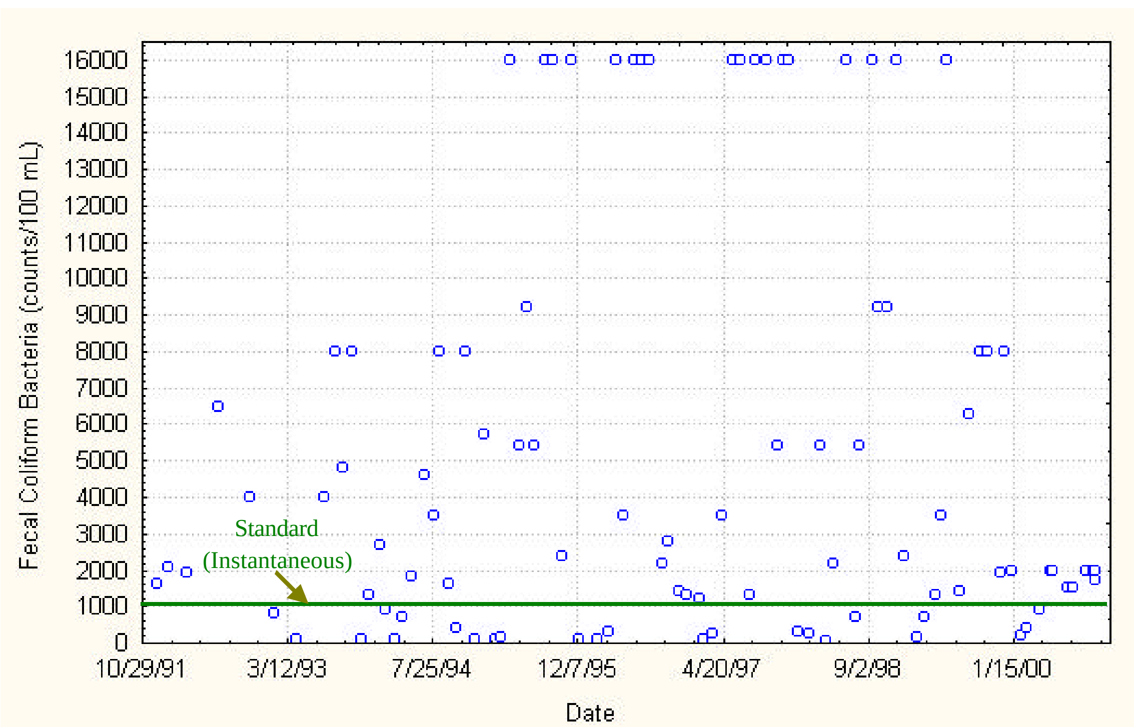

Figure 3.3 Blacks Run - fecal coliform bacteria data (12/91 - 10/00)

SECTION 4

SOURCE ASSESSMENT

Point and nonpoint sources of fecal coliform bacteria in the Cooks Creek watershed were considered in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources including, agricultural and land use information provided by VADCR, water quality monitoring and point source data provided by VADEQ, local housing and other spatial coverages provided by Rockingham County and the City of Harrisonburg, coordination with USGS (Blacks Run TMDL development), past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating fecal coliform bacteria loads are described in the following sections. Sources in the Blacks Run watershed were quantified by the USGS using similar loading estimation procedures and assumptions.

4.1 Assessment of Nonpoint Sources

Virginia's 1998 303(d) list identifies agricultural runoff as the primary source of pollutants in the Cooks Creek watershed. The lower three miles of Cooks Creek was also listed as impacted by urban nonpoint sources contributed by Blacks Run. Nonpoint sources of fecal coliform bacteria include septic systems, livestock (including manure application loads), wildlife, and domestic pets. The representation of the following sources in the model is discussed in Section 5.0. Sources in the Blacks Run watershed were quantified by the USGS and are presented in the fecal coliform bacteria TMDL for Blacks Run (USGS 2002).

4.1.1 Septic Systems and Straight Pipes

Residential septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. Fecal coliform bacteria naturally die-off as the effluent percolates through the soil to the groundwater. These systems effectively remove fecal coliform bacteria when properly installed and maintained.

A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff into surface waters. Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a stream and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

There are 1,147 unsewered houses (septic tanks) in the Cooks Creek watershed, excluding the Blacks Run subwatershed, as determined using the following methods. Unsewered houses were identified and digitized based on the location of structures, as depicted on USGS 7.5 minute topo maps (24K Digital Raster Graphics), and by using housing and sewer GIS coverages provided by Rockingham County and the City of Harrisonburg (E-911 data). Houses located within 300 feet of a sewer line were assumed to be connected to the regional sewer system. The location of unsewered houses was refined using the VADCR land use coverage for the Cooks Creek watershed. Houses located within high density residential, medium density residential, commercial, industrial, transportation, mixed urban, and open urban land use areas were also assumed to be connected to the sewer system. The population on septic was calculated using the Rockingham County census multiplier of 2.69 persons/house. The total septic population in the Cooks Creek watershed is 3,086.

The number of failing septic systems was estimated using a failure rate of 13.5%. This failure rate was based on information obtained by the USGS during the development of the Blacks Run fecal coliform TMDL. A fecal coliform bacteria concentration of 10^4 cfu/100mL and a septic system waste flow of 70 gallons/captia/day was used to estimate the contribution from failing septic systems to surface waters (Horsley and Witten 1996). In some cases, human waste is directly deposited into surface waters from houses without septic systems. These "straight pipes" and other illicit discharges are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located in close proximity to a stream. The number of straight pipes in the watershed was determined based on housing age and proximity to perennial streams. Older houses (pre-1967 and 1967-1985) located within 150 feet of a perennial stream were assumed to have a straight pipe according to the following percentages: pre-1967 (10% straight pipes), 1967-1985 (5% straight pipes). Using GIS analysis, one house in the Cooks Creek watershed was assumed to directly discharge into surface waters. Houses considered to have a normal functioning septic system were assumed to have a negligible contribution of fecal coliform bacteria to surface waters.

4.1.2 Livestock

Rockingham County ranks as the top agriculture producing county in Virginia, due in large part to livestock sales (NASS 1997 Census Data). Rockingham County is the leading producer of poultry (broilers, pullets, layers, and turkeys) and dairy cattle, ranks 3rd in beef cattle production, and is 2nd in sheep and lamb production (VASS 2001). Hogs are also raised in the county. Animal population estimates for the Cooks Creek watershed were based on the 1995 VADCR livestock inventory, as presented in Table 4.1. Horses, goats, and other livestock animals had very small populations as compared to the major livestock species listed above; therefore, the fecal loads from these animals were assumed to be negligible.

Table 4.1 VADCR livestock population estimates

Livestock Species	Cooks Creek Population (excluding the Blacks Run subwatershed)
Beef Cattle	1,880
Dairy Cattle	10,050
Hogs/Pigs	224
Sheep/Lambs	434
Chickens (pullets/layers)	66,797
Broilers	1,016,650
Turkeys	263,502

Fecal coliform bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Fecal coliform bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Grazing animals, such as beef and dairy cattle, typically spend portions of the day confined to loafing lots, grazing on pasture lands, and watering in nearby streams. The percentage of time spent in each area affects the relative contribution of fecal coliform bacteria loads to the stream. The amount of time beef and dairy cattle spend in or near streams primarily depends on time of year and the availability of stream access and off-stream watering facilities. Data collected by the USGS for the Blacks Run fecal coliform TMDL project, other regional TMDL studies, and local data sources were used to determine the amount of time beef and dairy cattle spend in these different areas. These data are presented in Tables 4.2 and 4.3. Beef cattle typically spend more time grazing in open areas than dairy cattle, which are confined for milking several hours a day. Sheep were assumed to be in pasture 100 percent of the time.

Table 4.2 Beef Cattle - percent of time spent grazing, in confinement, and in streams

Month	Grazing (hours)	Loafing Lot - Confinement (hours)	Stream Access (hours)
January	13.9	9.6	0.5
February	13.9	9.6	0.5
March	23.25	0	0.75
April	23	0	1.0
May	22.5	0	1.5
June	20.5	0	3.5
July	20.5	0	3.5
August	20.5	0	3.5
September	22.5	0	1.5
October	23	0	1
November	23.25	0	0.75
December	13.9	9.6	0.5

Table 4.3 Dairy Cattle - percent of time spent grazing, in confinement, and in streams

Month	Grazing (hours)	Loafing Lot - Confinement (hours)	Stream Access (hours)
January	5.5	18	0.5
February	5.5	18	0.5
March	13.65	9.6	0.75
April	15.8	7.2	1.0
May	15.3	7.2	1.5
June	13.3	7.2	3.5
July	13.3	7.2	3.5
August	13.3	7.2	3.5
September	15.3	7.2	1.5
October	15.8	7.2	1
November	13.65	9.6	0.75
December	5.5	18	0.5

Collected manure from livestock animals is applied to cropland and pasture in the Cooks Creek watershed, according to the following ratio: 75 percent is applied to cropland and 25 percent is applied to pasture. Dairy cattle and poultry manure represent the primary sources of land-applied livestock waste. Beef and dairy cattle manure is applied to cropland and pasture according to the schedule in Table 4.4. Turkeys and chickens are confined to poultry houses and hogs are confined to feed lots in the watershed; therefore, all litter produced is manually applied to cropland and pasture. The application of poultry manure for these species follows the schedule in listed in Table 4.5. Manure is applied to cropland during all months, except for June through August, due to the presence of a growing crop. The manure is used to fertilize corn and other primary crops in the spring and winter wheat in the fall. Tillage allows for the incorporation of fecal coliform bacteria that is applied to the soil surface. Based on field observations of cropland in the watershed, it was assumed that 25% of the manure that was applied was incorporated into the soil, resulting in 75% of the fecal coliform bacteria load being available for washoff.

Table 4.4 Beef and Dairy Cattle - Fraction of the annual manure application that is applied each month

Month	Beef Cattle Manure Fraction Applied	Dairy Cattle Manure Fraction Applied
January	0	0
February	0.05	0.05
March	0.25	0.25
April	0.2	0.2
May	0.05	0.05
June	0.05	0.1
July	0.05	0
August	0.05	0.05
September	0.1	0.15
October	0.1	0.05
November	0.1	0.1
December	0	0

Table 4.5. Turkeys/Chickens and Hogs - Fraction of the annual manure application that is applied each month

Month	Turkey/Chicken Manure Fraction Applied	Hog Manure Fraction Applied
January	0	0
February	0.05	0
March	0.25	0.075
April	0.2	0.158
May	0.05	0.134
June	0.05	0.134
July	0.05	0.134
August	0.05	0.134
September	0.1	0.159
October	0.1	0.075
November	0.1	0
December	0	0

Fecal coliform bacteria production rates used for livestock species in the Cooks Creek watershed are listed in Table 4.6. A variety of sources were consulted to determine the appropriate daily fecal coliform bacteria production value for each species, including the USGS Blacks Run TMDL, other TMDL studies, and literature sources.

Table 4.6. Livestock fecal coliform bacteria production rates

Livestock Species	Daily Production (cfu/animal/day)	Primary Source
Beef cattle	4.46×10^{10}	USGS 2002
Dairy cattle	3.90×10^{10}	USGS 2002
Chickens	6.75×10^{7}	ASAE 1998
Turkeys	9.30×10^{7}	ASAE 1998
Hogs/Pigs	1.08×10^{10}	ASAE 1998
Sheep	1.96×10^{10}	ASAE 1998

4.1.3 Wildlife

Wildlife species in the watershed were identified through consultation with the Virginia Department of Game and Inland Fisheries (VDGIF). The predominant species include ducks, geese, deer, beaver, raccoon, and muskrat. The population of each species was estimated using the population density per square mile of habitat area and the total area of suitable habitat in the watershed (Table 4.7). Habitat areas were determined using GIS and the land use coverage provided by VADCR. Population estimates and the defined habitat of each species in the Cooks Creek watershed (excluding the Blacks Run subwatershed) are listed in Table 4.8.

Table 4.7 Wildlife population density by land use (# animals per square mile of habitat)

Land Use	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
Cropland	30	40	50	70	0	5	15	320
Pasture/Hay	30	40	50	70	25	5	15	320
Forest	10	20	0	0	25	10	35	320
Built-Up (Urban)	30	40	50	70	0	5	15	320

Table 4.8 Wildlife habitat descriptions, population estimates, and percent of time spent in streams

Wildlife Species	Habitat Description	# of Animals	% in Streams
Ducks	100 meter buffer around perennial streams for all land uses	51 in summer 68 in winter	25%
Geese	100 meter buffer around perennial streams for Pasture/Hay, Cropland, and Built-Up	84 in summer 117 in winter	25
Deer	25 deer/mi^2 for Pasture and Forest	183 year-round	1
Beaver	20 meter buffer around perennial streams for all land uses	2 year-round	100
Raccoon	0.5 mile buffer around perennial streams for all land uses	176 year-round	5
Muskrat	20 meter buffer around perennial streams for all land uses	113 year-round	30

As with grazing livestock, wildlife deposit on the land and directly to surface waters. The percentage of fecal coliform bacteria that was directly deposited to surface waters was estimated based on the habitat of each species. The remaining fecal coliform load was applied to the upland landuses, according to the total area of each landuse within established habitat areas. The typical fecal coliform density for each wildlife species was used to calculate fecal coliform bacteria loads (Table 4.9).

Table 4.9 Fecal coliform bacteria production rates for wildlife species

Wildlife Species	Daily Production (cfu/animal/day)	Primary Source
Ducks	7.35×10^9	USGS 2002
Geese	7.99×10^8	USGS 2002
Deer	3.47×10^8	Yagow 1999
Beaver	2.0×10^5	MapTech 2000
Raccoon	5.0×10^9	Yagow 1999
Muskrat	2.5×10^7	Yagow 1999

4.1.4 Domestic Pets

Domestic pets, particularly dogs and cats, were also considered in source assessment and watershed modeling. Housing estimates (sewered and unsewered houses) were used to determine the number of pets in each subwatershed. Based on the assumption of one pet per household, the number of pets in the Cooks Creek watershed was estimated to be approximately 3,048. The fecal coliform concentration in dog waste (1.85×10^9 cfu/100mL - Mara and Oragui 1981) was used for all pets.

4.2 Assessment of Point Sources

Point sources, such as municipal sewage treatment plants, can contribute fecal coliform bacteria loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ.

There are currently four minor point source facilities in the Cooks Creek and Blacks Run watersheds (Table 4.10). Two of these facilities are located in the Blacks Run subwatershed (Figure 4.1). The U.S. Training and Development Center is the only facility that is permitted to discharge fecal coliform bacteria. This facility has a fecal coliform bacteria discharge limit of 200 cfu/100ml and a design flow of 0.001 mgd. This facility was addressed in the Blacks Run fecal coliform bacteria TMDL (USGS 2002).

Table 4.10 VPDES point source facilities

Stream	Facility Name	VPDES Permit No.	Discharge Type
Blacks Run	Frazier Quarry	VAG841011	Quarry water
	U.S. Training and Development Center	VAG401217	Municipal
Cooks Creek	Dayton WTP	VA0090085	Filter backwash
	Harrisonburg WTP	VA0002674	Filter backwash

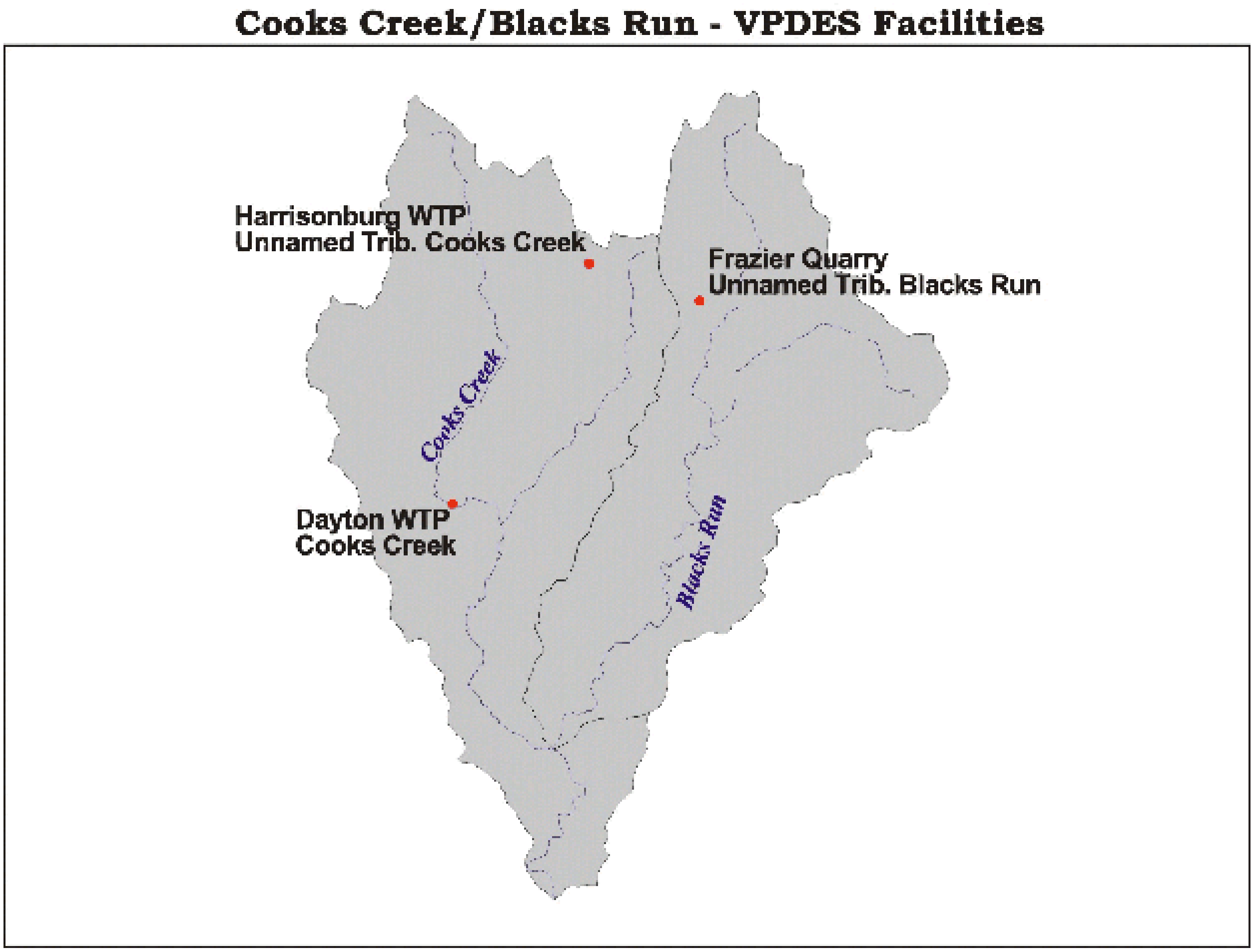

Figure 4.1 VPDES facilities (point sources) in the Cooks Creek and Blacks Run watersheds
* The U.S. Training and Development Center is not shown (permitted 9/01).

SECTION 5

WATERSHED MODELING

Establishing the relationship between the in-stream water quality targets and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

5.1 Modeling Framework Selection

The U.S. EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system Version 2.0 (USEPA 1998) and the Nonpoint Source Model (NPSM) were used to predict the significance of fecal coliform sources and fecal coliform levels in the Cooks Creek watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information (e.g. land uses, monitoring stations, point source dischargers). The NPSM model simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of pollutants through stream reaches. BASINS produces time series data, allowing for sufficient data to compare to the water quality target in the analysis.

5.2 Model Setup

The Cooks Creek watershed (including Blacks Run) was subdivided into ten subwatersheds to adequately represent the spatial variation in fecal coliform sources, watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations. Perennial and intermittent streams in the Cooks Creek watershed were digitized based on the location of “blue-line” streams as shown on the USGS 7.5 minute topographic maps of the area. The delineation of subwatersheds was based primarily on a topographic analysis of the watershed. Subwatersheds, primary streams, and the location of monitoring stations are shown in Figure 5.1. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

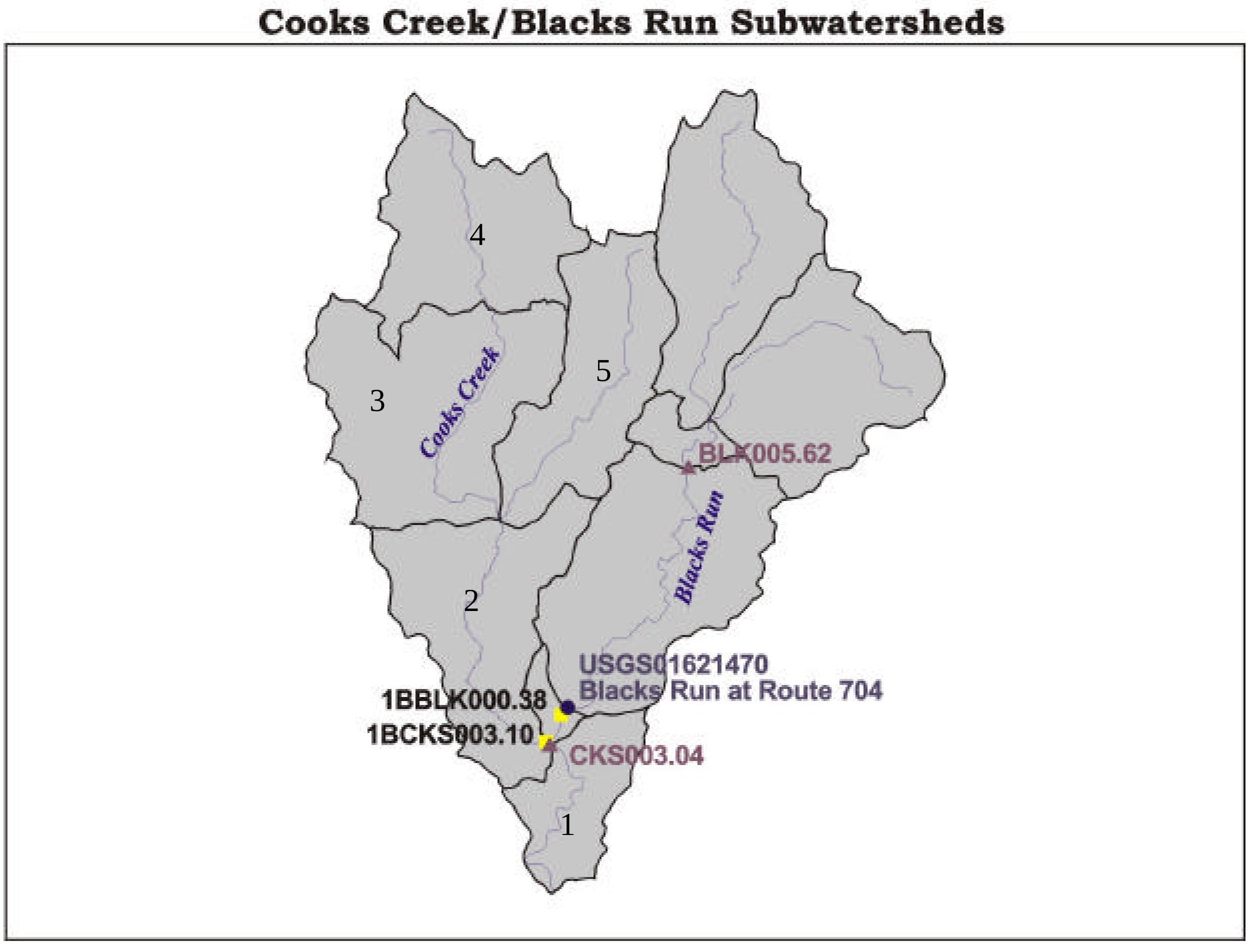

Figure 5.1 Cooks Creek/ Blacks Run subwatersheds and monitoring stations

Fecal coliform bacteria modeling data provided by the USGS were used to determine the existing and allocation load contributions from Blacks Run. As a result, fecal coliform bacteria loads from Blacks Run were treated as a point source in the model. The delineation of subwatersheds in the Blacks Run watershed was necessary for hydrology calibration, since the only active streamflow gage is located near the mouth of Blacks Run. The modeling of point sources in the watershed (including the Blacks Run contribution) and hydrology calibration procedures are discussed in detail later in this section.

5.3 Source Representation

Both point and nonpoint sources were represented in the model for Cooks Creek. In general, point sources were added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources were represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (e.g. animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream.

5.3.1 Failing Septic Systems

Septic systems provide the potential to deliver bacteria loads to surface waters due to system failures caused by improper maintenance and/or malfunctions. The number of septic systems in each watershed was determined using available housing and sewer GIS coverages provided by the Rockingham County and the City of Harrisonburg (Table 5.1). Houses in the watershed were digitized based on the location of structures, as depicted on USGS 7.5 minute topo maps (24K Digital Raster Graphics). The VADCR land use coverage for the Cooks Creek watershed was used to separate out sewered versus unsewered areas, depending on the classification of land use types. Using the Rockingham County census multiplier of 2.69 persons/house, the total septic population in each subwatershed was estimated. The number of failing septic systems was then calculated using a failure rate estimate of 13.5%. This failure rate was based on information obtained by the USGS during the development of the Blacks Run fecal coliform TMDL. In addition, data on housing age and proximity to a perennial stream were used to estimate the number of unsewered houses with a straight pipe (direct discharge). As detailed in section 4.1.1, older houses within close proximity to a stream had a greater likelihood of having a direct discharge. Build-up and washoff rates were used to calculate the fecal coliform bacteria load contributed to the stream by failing septic systems. 100% of the load from direct discharges was assumed to be transported to the stream.

Table 5.1. Total and failing septic population estimates (by subwatershed)

Subwatershed	Septic Population	Population served by failing septic systems
1	86	12
2	635	86
3	971	131
4	912	123
5	482	65

5.3.2 Livestock

Fecal coliform bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Fecal coliform bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Animal population estimates for the Cooks Creek watershed were based on the 1995 VADCR livestock inventory. Fecal coliform bacteria loads directed through each pathway were calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway.

The population of each livestock species was distributed among subwatersheds based on the total area of pasture and hayland in each subwatershed (Table 5.2). The number of beef and dairy cattle with stream access were estimated based on a GIS analysis of pasture and hayland areas that adjoin perennial streams and information on the time spent in streams. For each species, 80 percent of the animals with stream access were assumed to be in pasture and 20 percent were assumed to be in hayland areas (including improved pasture) at any time.

Table 5.2 Livestock population by subwatershed

Subwatershed	Beef Cattle	Dairy Cattle	Hogs	Sheep	Chickens (& Broilers)	Turkeys
1	140	747	17	32	80,496	19,577
2	354	1890	42	82	203,765	49,557
3	511	2730	61	119	294,393	71,589
4	431	2304	51	100	248,373	60,406
5	445	2379	53	103	256,459	62,373

Liquid manure from confined animals (cattle, chickens, and turkeys) is applied to cropland and hayland in the Cooks Creek watershed. In general, it was assumed that 75 percent of the manure application was applied to cropland, with 25 percent applied to pasture. Application rates vary monthly, with application primarily occurring during the spring and fall. Application of manure results in the accumulation of fecal coliform on the land surface. Therefore, fecal coliform accumulation rates are directly influenced by and based on the application rates of manure. To determine fecal coliform accumulation factors for the model, it was necessary to determine the amount of fecal coliform present in manure (refer to Section 4). The fraction of manure application available for runoff was calculated by subtracting the amount typically incorporated into the soil matrix through tillage and natural processes (assumed 25% soil incorporation).

Beef and dairy cattle in streams were represented in the model as direct inputs (e.g. point sources) of fecal coliform bacteria. Using the fecal coliform bacteria production rates for beef and dairy cattle, the daily contribution of fecal coliform bacteria from cattle in streams was calculated and then totaled by subwatershed depending on the population estimates of beef and dairy cattle watering in streams in each subwatershed (refer to Section 4.1.2). Fecal coliform bacteria contributions from cattle in streams were represented in the model using the total load delivered to the stream (#/day) and the flow rate at which it is delivered (cfs). The flow rate was determined using the amount of waste produced by beef and dairy cattle each day (lb/day) and an assumed density of the manure produced (lb/gal). Cattle in the stream were assumed to discharge at a constant rate.

Grazing animals also contribute fecal coliform bacteria to the land surface, which is available for washoff to surface waters during storm events. Beef and dairy cattle were the most abundant grazing animals in the watershed, as shown in Table 5.2 Sheep represent the only other significant grazing livestock species in the Cooks Creek watershed. Cattle and sheep were distributed throughout pasture and hayland areas in each subwatershed. Fecal coliform accumulation rates (#/acre/day) for each of these livestock species were calculated using subwatershed population estimates and the fecal coliform production rate established for each species.

5.3.3 Wildlife

The population of each wildlife species was estimated using the population density per square mile of habitat and the total area of suitable habitat in each subwatershed (Table 5.3). As with grazing livestock, wildlife deposit manure on the land and directly to surface waters. The habitat and percentage of time each species typically spends in streams was used to determine the proportion of fecal coliform bacteria that was deposited on land versus directly to surface waters. Loads applied to the land (in each subwatershed) were distributed according to the total area of each land use type within the established habitat area of each species.

Table 5.3 Wildlife population by subwatershed

Subwatershed	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
1	10	14	17	24	12	0.4	28	24
2	15	20	25	35	31	0.6	56	34
3	16	22	27	38	50	0.6	53	36
4	0.5	0.7	0.8	1.2	52	0.02	7	1
5	8	11	14	19	38	0.3	32	17

5.3.4 Domestic Pets

Housing estimates (number of sewered and unsewered houses) were used to determine the number of pets in each Cooks Creek subwatershed. An assumption of one pet per household was used to calculate the pet population. Fecal coliform bacteria loading from pets was applied to urban (built-up) lands in each subwatershed.

5.4 Stream Characteristics

The channel geometry for the stream reaches in Cooks Creek subwatersheds were based on the visual observation of stream channel configurations throughout the watershed and through an analysis of typical stream channel geometry values for these stream types. The stream segment length and slope values for each subwatershed were determined using GIS analysis of digitized streams and digital elevation models (DEMs).

5.5 Selection of a Representative Modeling Period

The selection of a representative modeling period was based on the availability of stream flow and water quality data collected in the Cooks Creek watershed that cover varying wet and dry time periods. Hourly flow discharge data were available from the USGS gage located near the mouth of Blacks Run (USGS01621470, Route 704 road crossing) from February 20, 1999 through November 26, 2000. Monthly water quality data were also collected by VADEQ on Cooks Creek and Blacks Run during this period; therefore, this time period was selected for modeling purposes. Local weather data obtained from the USGS gage on Blacks Run and the Dale Enterprise meteorological station were used in model runs. This time period represented varying climatic and hydrologic conditions, including dry, average, and wet periods that typically occur in the area. This was an important consideration because during dry weather and low flow, constant direct discharges dominate the impact on instream concentrations; however, during wet weather and high flow periods, surface runoff delivers nonpoint source fecal coliform to the stream, affecting the instream conditions more than constant discharges.

5.6 Model Calibration Process

To develop a representative linkage between the sources and the instream water quality response in the Cooks Creek watershed, model parameters were adjusted to accurately represent hydrology and fecal coliform bacteria loading. Hydrologic calibration was based on quantitative comparisons between modeled streamflow and observed streamflow upstream of the USGS gage on Blacks Run, because of the lack of streamflow data collected on Cooks Creek. Hydrologic parameter values calibrated to represent the flow regime in Blacks Run were used to set up the Cooks Creek model.

Figure 5.2 shows the observed and modeled flows for the period of record. Model parameters which relate to surface water runoff, water balance, and groundwater flow were adjusted within reasonable limits until predicted flows adequately matched observed values. Adjusted parameters represent groundwater storage, evapotranspiration, infiltration capacity of the soil, interflow, and overland flow length. Based on this examination and a verification that parameter values were reasonable, it was determined that the model adequately represents the hydrology of Blacks Run. Calibration statistics and their acceptable ranges are given in Table 5.4. Following hydrology calibration, an independent time period is typically selected and modeled in order to assess and validate the calibration results. Due to the limited streamflow record, a validation period was not specified in order to maximize the length of the calibration time period.

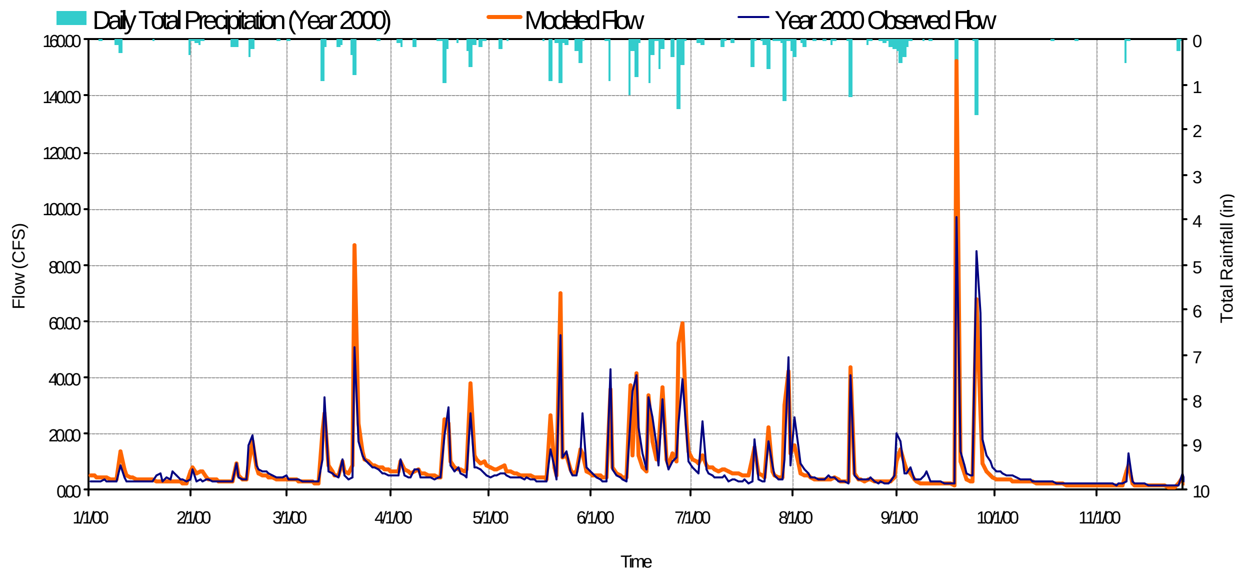

Figure 5.2 Hydrology calibration results for the period 1/1/00 through 11/26/00

Table 5.4 Hydrology calibration performance statistics (Water Year 2000)

Flow Calibration Parameter	Simulated (in.)	Observed (in.)	% Error	Recommended% Error Limit
Total volume (runoff)	5.69	5.45	4.29%	10%
Total of lowest 50% flows	1.06	1.09	-3.03%	10%
Total of highest 10% flows	2.52	2.39	5.20%	15%
Summer volume	1.71	1.73	-1.20%	30%
Winter volume	1.22	1.07	12.33%	30%
Summer storm volume	1.46	1.37	6.09%	50%

The VADEQ water quality station on Cooks Creek is located just upstream of the confluence with Blacks Run; therefore, water quality calibration was based on the model output at this location and does not incorporate the contribution from Blacks Run. Fecal coliform accumulation and surface loading parameters for land uses were calculated based on contributions from various sources, as discussed in Section 4. After incorporating these model parameters and inputs, as well as contributions from livestock and wildlife point sources, septic systems, and background concentrations in the streams, modeled in-stream fecal coliform bacteria concentrations were compared to observed data. The modeled concentrations closely correspond to the observed fecal coliform values, as shown in Figure 5.3. The relative pattern of observed concentration levels is maintained in the modeled concentrations. It should be noted that the difference between the highest fecal coliform observed values and the modeled peak concentrations is due to laboratory detection limits which cap the maximum reported concentration at either 8,000 cfu/100mL or 16,000 cfu/100mL, depending on when the samples were collected and which laboratory protocol was used. Because of these maximum laboratory detection limits, the measured value of the sample may be significantly lower than the actual value.

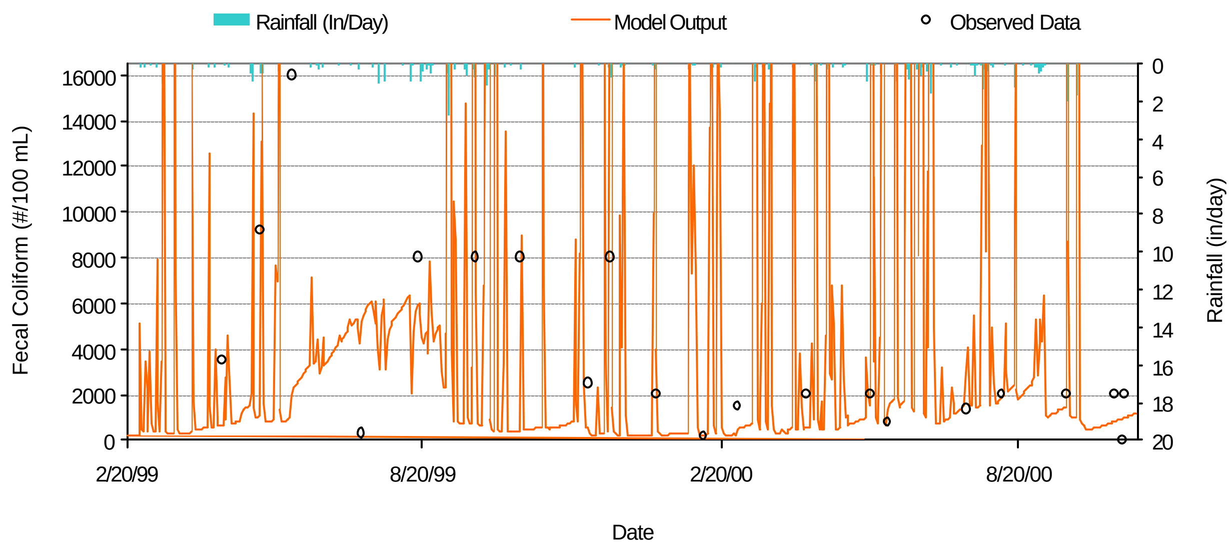

Figure 5.3 Water quality calibration at the VADEQ station on Cooks Creek (1BCKS003.10) for the modeling period

5.7 Existing Loadings

The model was run for the representative hydrologic period (February 20, 1999 through November 26, 2000). The modeling run represents the existing bacteria concentrations and loadings at each subwatershed outlet. Figure 5.4 shows the time series geometric mean concentrations of fecal coliform bacteria under existing conditions for Cooks Creek (at the mouth and upstream of Blacks Run) and the Blacks Run inflow. These data were compared to the 200 cfu/100mL geometric mean water quality standard to assess the magnitude of in-stream concentrations. Existing fecal coliform bacteria loadings by land use category for Cooks Creek subwatersheds are presented in Section 6. These values represent the contribution of fecal coliform bacteria from all sources in each subwatershed, not including inflows from upstream subwatersheds. Note that the Blacks Run fecal coliform bacteria contribution was added as a point source into the downstream subwatershed in allocation scenarios.

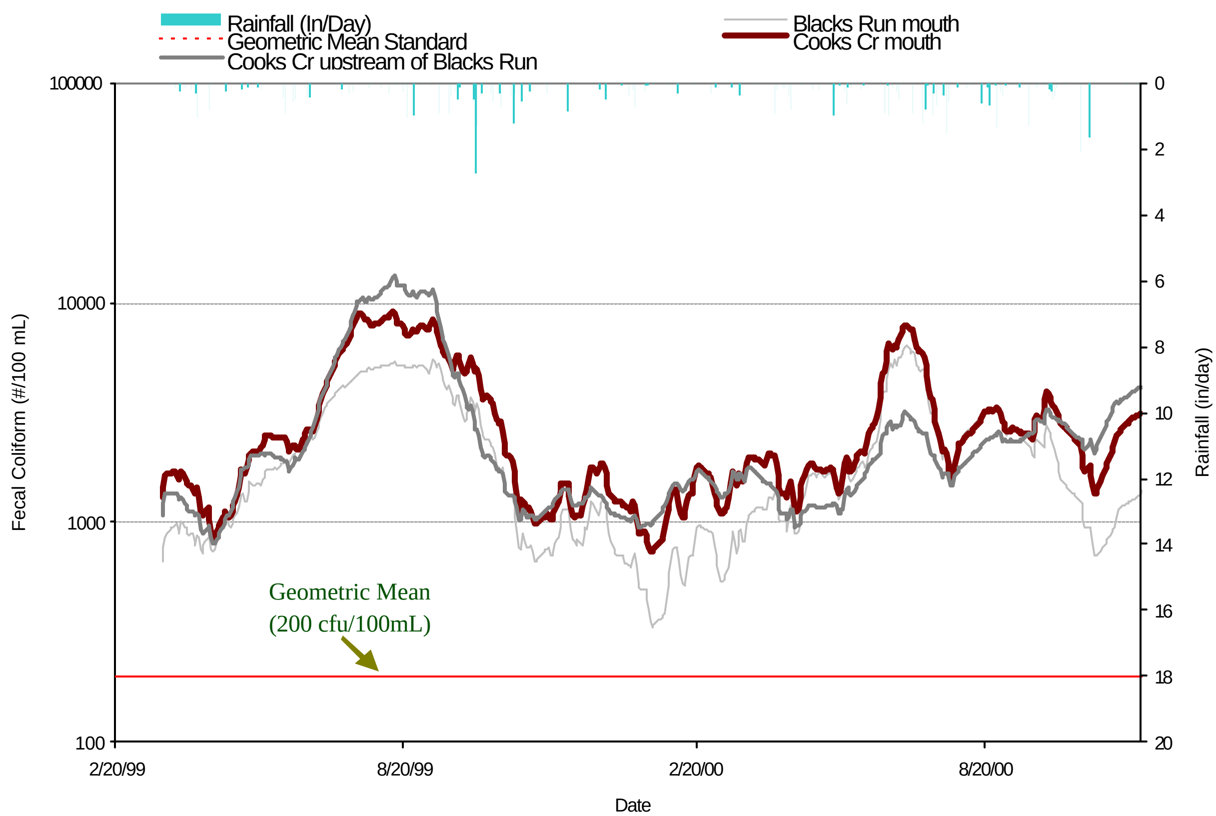

Figure 5.4 Existing conditions - time series geometric mean concentrations for Cooks Creek and Blacks Run

SECTION 6

TMDL METHODOLOGY

6.1 TMDL Calculation

The fecal coliform bacteria TMDL established for Cooks Creek consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. For fecal coliform bacteria, TMDLs are expressed in terms of bacteria counts (or resulting concentration).

The TMDL equation is as follows:
TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources (e.g. sewage treatment plants). The LA portion represents the loading assigned to nonpoint sources (e.g. septic discharges, cattle direct deposition). The MOS is the portion of loading reserved to account for any uncertainty in the data and the modeling process. A geometric mean of 200 cfu/100mL was established as the TMDL value, based on the fecal coliform bacteria criteria specified in Virginia's Water Quality Standards (Section 1). An explicit MOS of 5 percent (10 cfu/100mL) was used in TMDL calculations; therefore, the sum of WLAs and LAs must not exceed 190 cfu/100mL. Implicit MOS factors were also incorporated into the TMDL development process through the use of conservative model assumptions and source load estimates.

6.2 Wasteload Allocations

There are currently four minor point source facilities in the Cooks Creek and Blacks Run watersheds (Table 4.8). Two of these facilities are located in the Blacks Run subwatershed (Figure 4.1). The U.S. Training and Development Center is the only facility that is permitted to discharge fecal coliform bacteria. This facility was addressed in the Blacks Run fecal coliform bacteria TMDL (USGS 2002); therefore the Cooks Creek WLA equals zero.

6.3 Load Allocations

Load allocations to nonpoint sources are divided into land-based loads from land uses in the watershed and direct discharges from septic systems, cattle, wildlife, and pets.

Using the model developed to represent existing conditions, various allocation scenarios were examined for reducing fecal coliform loads to levels that would result in the attainment of water quality standards. This examination focused on understanding the water quality response and sensitivity of Cooks Creek to variations in source loading characteristics.

Allocation scenarios that meet the 30-day geometric mean standard concentration of 190 cfu/100mL (less 5% MOS) are presented in Table 6.1. The time series 30-day geometric mean concentration for existing and allocation scenarios are shown in Figure 6.1. Reductions in load contributions from cattle in streams had the greatest impact on fecal coliform concentrations. Significant reductions from all other sources, including land-based loadings and wildlife direct depostion were also required to meet the geometric mean standard. Although the amount of fecal coliform bacteria that is produced by sources such as wildlife are far less than the loads that are produced by livestock in the watershed, reductions in these sources were also required due to the magnitude of fecal coliform concentration in the streams. Direct deposition during low flow conditions and loads transported by runoff during high flow conditions are controlled in these allocation scenarios. Forest contributions represents the natural condition and therefore were not reduced in allocation scenarios. Note that the Blacks Run geometric mean concentration used in allocation scenarios was based on the TMDL allocated load that was calculated for this stream in the Blacks Run TMDL study (USGS 2002).

Table 6.1 TMDL allocation scenarios

Source Category	*Scenario 1 (% reduction)	Scenario 2 (% reduction)	Scenario 3 (% reduction)
Cropland	99%	99%	99%
Pastureland (incl. hayland)	99	99	99
Forest Land	0	0	0
Built-Up Land	99	99	99
Interflow & Groundwater	99	99	99
Cattle in streams	100	100	99
Wildlife in streams	0	97	97
Septic systems (failing & uncontrolled discharges)	100	100	99
Blacks Run inflow	0	0	50

* Scenario 1 does not meet the geometric mean standard of 190 cfu/100mL (less 5% MOS)

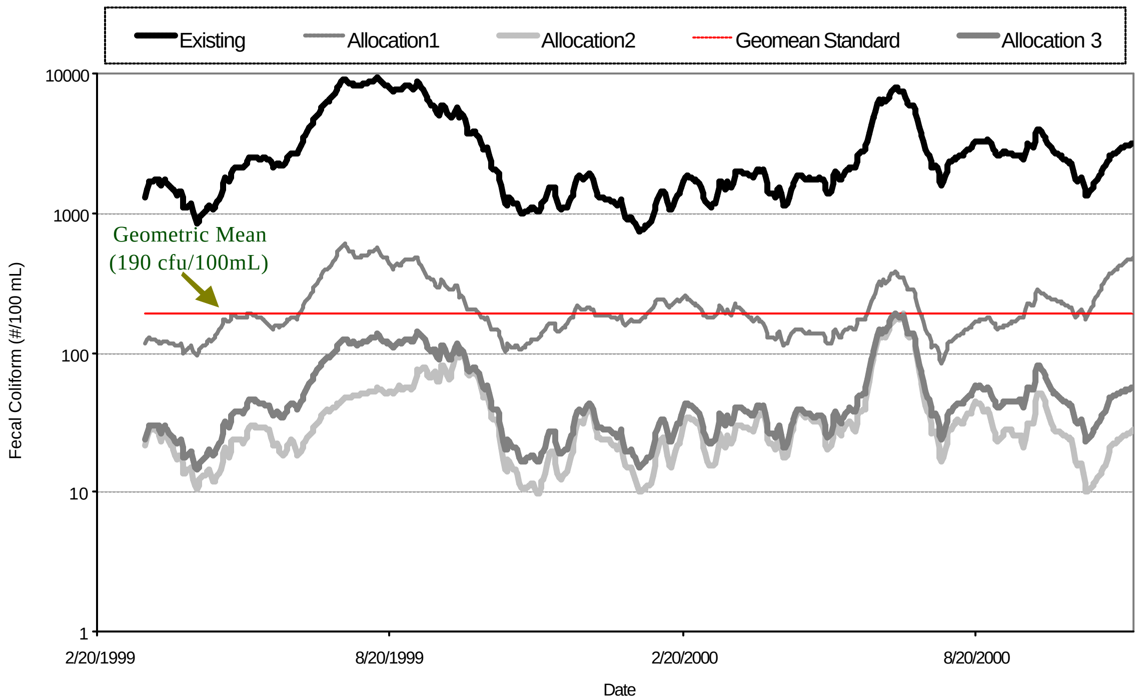

Figure 6.1 Time series geometric mean concentrations for existing and allocation scenarios

The existing and allocation loads under Scenario 2 are presented in Table 6.2. This scenario does not propose reductions to forest lands and holds the Blacks Run TMDL allocation loads fixed (no additional reduction). The load allocation in this scenario includes a 99% reduction in all land-based sources in the watershed, a 100% reduction in direct deposition of fecal coliform bacteria from cattle, a 100% reduction in contributions from failing septic systems and any unpermitted discharges, and a 97% reduction in wildlife direct deposition into streams. Other allocation scenarios which meet the geometric mean standard (less 5% MOS) required reductions in loads from forest lands and/or from the previously allocated Blacks Run contribution. The required source load reductions were similar to the findings in the Blacks Run TMDL study.

Table 6.2 Existing and allocation loads for each subwatershed under Allocation Scenario 2

Land-Based Contributions				
Existing Scenario				
SWS	Built-Up	Cropland	Forest	Pasture
1	9.58E+12	1.09E+14	6.97E+10	2.17E+14
2	2.24E+13	2.94E+14	2.13E+11	5.50E+14
3	3.91E+13	4.25E+14	5.86E+11	7.94E+14
4	1.47E+13	3.55E+14	1.07E+12	6.70E+14
5	3.80E+13	3.60E+14	2.08E+11	6.92E+14
Allocation Scenario #2				
SWS	Built-Up	Cropland	* Forest	Pasture
1	9.58E+10	1.09E+12	4.02E+09	2.17E+12
2	2.26E+11	2.98E+12	5.98E+09	5.50E+12
3	3.08E+11	4.25E+12	1.41E+10	7.94E+12
4	1.40E+11	3.55E+12	1.30E+10	6.70E+12
5	3.31E+11	3.60E+12	5.58E+09	6.92E+12

*Subsurface concentrations reduced 99%, surface accumulation rate same as existing.

In-Stream Contributions									
Existing Scenario	**In-Stream Cattle (# for simulation period)**			**In-Stream Septics (# for simulation period)**			**In-Stream Wildlife (# for simulation period)**		
Reach	Existing	Allocation 2	Percent Reduction	Existing	Allocation 2	Percent Reduction	Existing	Allocation 2	Percent Reduction
001	4.88E+13	0	100	2.47E+12	0	100	2.53E+13	7.60E+11	97
002	3.30E+13	0	100	1.82E+13	0	100	3.97E+13	1.19E+12	97
003	3.96E+13	0	100	2.79E+13	0	100	4.17E+13	1.25E+12	97
004	2.86E+12	0	100	2.62E+13	0	100	2.56E+12	7.67E+10	97
005	3.28E+12	0	100	1.38E+13	0	100	2.18E+13	6.53E+11	97

6.4 Consideration of Critical Conditions

The NPSM model is a continuous-simulation model; therefore, all flow conditions are taken into account for loading calculations. The modeling period represents typical high and low flow periods in the watershed; therefore, loads contributed through direct deposition (e.g. cattle in streams) and through runoff under critical conditions were accounted for in the model.

6.5 Consideration of Seasonal Variations

Seasonal variation was explicitly included in the modeling approach for this TMDL. Fecal coliform accumulation rates for each land use were determined on a monthly basis. The monthly accumulation rates accounted for the temporal variation in activities within the watershed, including seasonal application of agricultural waste, grazing schedules of livestock, and seasonal variation in number of cows in the stream. Also, the use of continuous simulation modeling resulted in consideration of the seasonal aspects of rainfall patterns. In addition, seasonal variation was accounted for in the allocation scenario. Reductions of fecal coliform loads were determined on a monthly basis by each land use in each subwatershed.

SECTION 7

REASONABLE ASSURANCE AND IMPLEMENTATION

7.1 Follow-Up Monitoring

The Department of Environmental Quality will continue to monitor Blacks Run and Cooks Creek in accordance with its ambient monitoring program. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

7.2 TMDL Implementation Process

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be to develop a TMDL implementation plan, and the final step is to implement the TMDL until water quality standards are attained.

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are:

1. as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved;
2. it provides a measure of quality control, given the uncertainties which exist in any model;
3. it provides a mechanism for developing public support;
4. it helps to ensure the most cost effective practices are implemented initially; and
5. it allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan as outlined below. While specific goals for BMP implementation will be established as part of the implementation plan development process, some general guidelines and suggestions are outlined below:

In general, the Commonwealth intends for the required reductions to be implemented in an iterative process that addresses the sources with the largest impact on water quality first. For example, the most promising management practice in agricultural areas of the watershed is livestock exclusion from streams. This has been shown to be very effective in lowering fecal coliform concentrations in streams, both from the cattle deposits themselves and from additional buffering in the riparian zone. Additionally, reducing the human bacteria loading from failing septic systems should be a focus during the first stage because of its health implications. This component could be implemented through education on septic pump-outs and other activities.

During the second stage of implementation, increased stockpiling of poultry litter may be an appropriate management measure to pursue, following research on the required storage time needed to remove fecal coliform bacteria. Management practices that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

7.3 Regulatory Framework

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, including implementation plans as a TMDL requirement has been discussed for future federal regulations. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

DEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 7.4 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

7.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's Conservation Reserve Enhancement Program (CREP), the USDA's Environmental Quality Implementation Program (EQIP), the state revolving loan program, the VA Water Quality Improvement Fund, the VA Cost-Share Program, and tax credit programs.

7.5 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all of the sources of fecal coliform (other than wildlife), the stream will not attain standards. As is the case for Blacks Run and Cooks Creek, TMDL allocation reductions of this magnitude are not realistic and do not meet EPA's guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** This is obviously an impractical action. While managing over-populations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. In such a case, after demonstrating that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs, the state may decide to re-designate the stream's use for secondary contact recreation or to adopt site specific criteria based on natural background levels of fecal coliforms. The state must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs through a so-called Use Attainability Analysis (UAA) as described in chapter 1. All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process.

Based on the above, EPA and Virginia have developed a TMDL strategy to address the wildlife issue. The first step in this strategy is to develop interim reduction goals. The pollutant reductions for the interim goal are applied only to controllable, anthropogenic sources identified in the TMDL, setting aside any control strategies for wildlife. During the first implementation phase, all controllable sources would be reduced to the maximum extent practicable using the staged approach outlined above. Following completion of the first phase, VADEQ would re-assess water quality in the stream to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the second phase because the water quality standard exceedances attributed to wildlife in the model are very small and infrequent and may fall within the margin of error.

SECTION 8

PUBLIC PARTICIPATION

The first public meeting on the development of TMDLs for Blacks Run and Cooks Creek was held on April 12, 2001 from 7-10 p.m. at Pence Middle School in the Town of Dayton. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on March 26, 2001 (Volume 17, Issue 14). Copies of the presentation materials were made available for public distribution at the meeting. The public comment period ended on April 20, 2001. Eleven people attended the first public meeting. One comment letter was received and was responded to in writing.

The second public meeting on the development of TMDLs for Blacks Run and Cooks Creek was held on March 28, 2002 from 7-10 p.m. at the VADEQ Valley Regional Office in the City of Harrisonburg. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on March 11, 2002. Copies of the draft TMDL reports and presentation materials were made available for public distribution at the meeting. The public comment period ended on April 19, 2002. Fourteen people attended the second public meeting. No written comments were received.

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